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FILM-FORMING DEVICE FOR ORGANIC THIN-FILM LIGHT-EMITTING DIODE
[Yuki yakumaku hakko soshi no seimaku sochi]

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[Title of the Invention] /1*

Film-Forming Device for Organic Thin-Film Light-Emitting diode

[Claim(s)] /2

[Claim 1] A film-forming device for an organic thin-film light-emitting diode comprising an organic light-emitting layer which emits light by the recombination of electrons and positive holes; said film-forming device for an organic thin-film light-emitting diode characterized by comprising dust accumulating adhesion parts to be freely replaced, wherein parts, which are outside the element substrate inside a film-forming chamber, and are present in potions where an organic or inorganic material evaporated from its vapor deposition source is accumulated as dust, are mounted on the same support body.

[Claim 2] The film-forming device of Claim 1 in which a film-forming chamber is equipped, via a vacuum valve, with a load cell chamber to which a vacuum pump is connected in order to enable replacement of dust accumulating on a set of parts while maintaining said film-forming chamber in a vacuum state.

[Claim 3] The film-forming device of Claim 1 or 2 comprising a preheating chamber having a temperature regulating means for said vapor deposition source and a means for maintaining the vacuum state as a chamber for performing an initialization operation of the vapor deposition source used in the film formation of an organic or

*Numbers in the margin indicate pagination in the foreign text.

inorganic material, with the preheating chamber being spaced apart from the film-forming chamber.

[Claim 4] The film-forming device of Claim 3, wherein said preheating chamber is connected to said film-forming chamber via a vacuum valve to enable transfer of the vapor deposition source between the preheating chamber and the film-forming chamber while the film-forming chamber is maintained in the vacuum state.

[Claim 5] The film-forming device of Claim 4 comprising a plurality of the sets of parts accumulated with dust and the load lock chamber functioning as a preheating chamber.

[Claim 6] A film-forming device for an organic thin-film light-emitting diode comprising an organic light-emitting layer which emits light by the recombination of electrons and positive holes; said film-forming device for an organic thin-film light-emitting diode characterized by comprising a preheating chamber having a temperature regulating means for said vapor deposition source and a means for maintaining the vacuum state as a chamber for performing an initialization operation of the vapor deposition source used in the film formation of an organic or inorganic material, with the preheating chamber being spaced apart from the film-forming chamber.

[Claim 7] The film-forming device of Claim 6, wherein said preheating chamber is connected to said film-forming chamber via a vacuum valve to enable transfer of the vapor deposition source between the preheating chamber and the film-forming chamber while the

film-forming chamber is maintained in the vacuum state.

[Detailed Specifications]

[0001] [Technical Field of the Invention]

The present invention relates to a film-forming device (vacuum vapor deposition device) for manufacturing an organic light-emitting diode used as a display device.

[0002] [Prior Art]

An electroluminescent element exhibits high visibility due to characteristics of self-luminosity. The electroluminescent element exhibits excellent resistance against impacts since the electroluminescent element is made of a complete solid-state material. The electroluminescent element is used in various display devices. Moreover, the organic thin-film light-emitting diode, which is an electroluminescent element using organic materials, has attracted much attention, since the organic thin-film light-emitting diode can greatly lower the driving voltage required or luminescence, and all the colors may be illuminated by applying various light-emitting materials.

[0003] Particularly after Tang et al. disclosed an organic thin-film light-emitting diode that emits light with a high-luminance of 1000 cd/m^2 at a low applied voltage of 10 V in 1987 (cf. Applied Phys. Lett., 51 (1987): 913), the development of practical element structures, various materials, and manufacturing techniques has been actively conducted.

[0004] The layered construction of the concerned organic thin-film light-emitting diode will be described on the basis of Figure 1. Figure 1 is a cross section showing a typical elemental structure of an organic thin-film light-emitting diode, which is a light-emitting diode, including an anode layer 2, a hole injection layer 3, a light-emitting layer 4, an electron injection layer 5, and a cathode layer 6, formed and laminated successively one on the other in that order on a light-transmitting substrate 1. The thin-film light-emitting diode is used as a display device by applying a drive voltage supplied from an external power supply 7 across the anode 2 and the cathode 6 to control the light generated from the light emitting layer 4.

[0005] It is necessary that the organic light emitting material be easily formed in the form of a film, to exhibit a high light-emitting efficiency, and to be stable. Additionally, it is required for the charge injection material to be easily formed in the form of a film, to be highly efficient in charge transport and charge injection into the light emitting layer, and to be stable. Tokukai No. H2-311591 and No. S59-194393 disclose the preferable materials.

[0006] Although the method for forming the organic layer and the inorganic layer include a vapor phase growth method and a liquid phase growth method, the vapor phase growth is generally used for forming the organic and inorganic layers of the organic thin-film light-emitting diode. Since the organic materials for forming the

organic layers generally are soluble in organic and inorganic solvents, it is difficult to laminate the organic layers by the liquid phase growth method.

[0007] Forms of a device for forming an organic thin-film light-emitting diode when employing a vacuum vapor deposition method, which is a vapor phase growth method, are shown in Figures 7, 8 and 9. All of these are vacuum vapor deposition devices for forming three layers of film using three vapor deposition sources. Figure 7 is a batch-type device, which is a form for sequentially performing film formation of the organic and inorganic layers of the organic thin-film light-emitting diode in a plurality of film-forming chambers 10a, 10b and 10c. These film-forming chambers are connected via a vacuum valve 11, and vapor deposition sources 8a, 8b and 8c are installed underneath shutters 12, respectively. Figure 8 is a single-wafer-type device that includes the plurality of vapor deposition sources 8a, 8b and 8c inside one film-forming chamber 10 in a form for removing an element substrate 9 after forming a multilayered film. Figure 9 is a transfer-type device which has the plurality of vapor deposition sources 8a, 8b and 8c situated underneath the shutters 12 in the one film-forming chamber 10, as with the single-wafer-type device. But in this case, the plurality of elements can be continuously formed as films simultaneously so that there is a transfer function to the element substrate 9.

[0008] [Problems to be Solved by the Invention]

When the organic and inorganic layers of the organic thin-film light-emitting diode are formed as films using the film-forming devices, as shown in Figures 7, 8 and 9, there is a problem because it is difficult to increase the rate of operation of the film-forming device. Three reasons thereof are cited next.

① With an organic thin film vapor deposition using a vacuum vapor deposition device, the organic material is vapor deposited on an element substrate from a vapor deposition source, after which it is necessary to perform a maintenance operation to clean the inside of the film-forming chambers, except the element substrate on which /3 the organic material was accumulated, for every single vapor deposition.

② After new organic and inorganic materials are installed as vapor deposition sources each time, or after the vapor deposition sources are exposed to air by breaking the vacuum state inside the vacuum vapor deposition device, it is always necessary to perform an initialization operation of the vacuum vapor source, such as a degassing operation of the vacuum vapor source.

③ The film-forming operation must be suspended when use of the vacuum vapor source becomes impossible, since the organic and inorganic materials become used up.

The aforesaid reasons ① and ② among these three reasons will now be described in detail.

[0009] The aforesaid reason in ① is described first. With the vacuum vapor deposition device, the organic and inorganic raw materials evaporated from the vacuum vapor sources in the step of vapor depositing the organic and inorganic materials primarily accumulate as dust, like a vapor deposited film, on the five elements below inside the following vacuum vapor deposition device.

Element 1: A vacuum vapor source composed of organic and inorganic materials evaporated in a vacuum in a heating method, such as resistance heating, and a boat, crucible or the like for heating the materials.

Element 2: A mask for shielding a pattern shape from the vapor flow of materials used in a process for vapor depositing the materials evaporated from the vacuum vapor sources on the element substrate.

Element 3: A shutter for allowing a material vapor flow to pass through or be blocked in a process for starting or ending the vapor deposition of the materials evaporated from the vacuum vapor sources on the element substrate.

Element 4: A sensor for observing the vapor deposited film thickness and the vapor deposition speed when the materials evaporated from the vacuum vapor sources are vapor deposited on the

element substrate.

Element 5: A shield for preventing the materials evaporated from the vacuum vapor sources from accumulating, except on the element substrate in the film-forming chamber.

[0010] The organic material accumulated on the shielding plate, mask, shutter, sensor, evaporation source, and the like peels easily inside the vacuum vapor deposition device. The cause of this is that the heat stability of the organic material is low, or because of the insulative nature of the organic material and its low density, or the majority of the shielding plate, mask, shutter, sensor, evaporation source, and the like on which the organic material accumulates is composed of an inorganic material, such as aluminum or SUS; hence, the fact that the difference in the coefficient of thermal expansion between it and the accumulated organic material is large, among other reasons, are cited.

[0011] When film formation of the organic thin film is continually performed using the shielding plate, mask, shutter, sensor, evaporation source, and the like in a state in which the organic material has accumulated thereon, a problem occurs because the organic material which has peeled from these elements contaminates the inside of the organic thin-film light-emitting diode as a powdery dust.

[0012] The size of the powder dust varies depending on the manner of peeling, the type of material, the vapor deposition rate

during film formation and the structure of the film-forming device. The size of the powdery dust ranges on the order of from several Å to several mm. On the other hand, the film thickness of the organic light-emitting diode is very thin and the thickness thereof ranges on the order of from several tens of nm to several hundreds of nm. Therefore, if the powdery dust having approximately the layer thickness size merely contaminates the inside of the light-emitting diode, it causes dark spots due to the coagulation of the organic materials, a leakage current due to localization of the electric field, and a chemical change in the organic layer, whereby shortening of life of the light-emitting layer, increasing of defective light-emitting portions, luminous and color fluctuations, and the like are caused. Therefore, the inclusion of the powdery dust in the light-emitting diode causes serious problems in putting the organic thin-film light-emitting diode into practice.

[0013] Therefore, it is difficult to increase the rate of operation of the film-forming device and the manufacturing costs rise since it is necessary to frequently perform a maintenance operation for cleaning the inside of the film-forming chamber on which the organic material accumulated, except the element substrate.

[0014] The aforesaid reason in ② is described next. It is necessary to break the vacuum state inside the vacuum vapor deposition device to clean the film-forming chamber, except the

element substrate, on which the organic material accumulated in the step of vapor depositing the organic thin film by using the vacuum vapor deposition device. Once the vacuum state inside the vacuum vapor deposition device is broken, substances in the air, such as hydrogen, water, carbon monoxide and carbon dioxide, are adsorbed onto the vapor deposition sources. In manufacturing the organic thin-film light-emitting diode, the vacuum vapor deposition device was heated to a certain temperature, kept at that temperature and cooled to degas the vapor deposition sources before the organic thin film formation. If the heating, temperature maintenance, and cooling operations are not performed before the organic thin film is formed in order to perform the degassing operation on the vapor deposition sources, the substances adsorbed, such as hydrogen, water, carbon monoxide and carbon dioxide, contaminate the organic thin-film light-emitting diode.

[0015] The inclusion of the substances thus adsorbed especially inside the organic thin-film light-emitting diode causes lowering of the injection efficiencies of the electron and the positive hole injected from the electrodes to the light-emitting layer of the organic thin-film light-emitting diode, a chemical change in the light-emitting layer, etc. Since the lowering of the injection efficiencies and the chemical change further causes lowering of the luminance of the organic thin-film light-emitting diode, the inclusion of the gas constituents poses serious problems impeding the

practical use of the organic thin-film light-emitting diode.

[0016] In addition, when a new vapor deposition source for the organic and inorganic materials is installed, the formation of a uniform organic and inorganic thin film may not be performed immediately after heating the new vapor deposition sources, if special heating, temperature-maintaining, and cooling treatments are not performed.

[0017] Thus, with the manufacture of the organic thin-film light-emitting diode, it is difficult to increase the rate of operation of the film-forming device and to lower the manufacturing cost, since it is always necessary to conduct the initializing operation of the vapor deposition sources including degassing of the vapor deposition sources after conducting the maintenance operation described in (1) above frequently and to install new vapor deposition sources for the organic and inorganic materials.

[0018] As described above, one batch step in the conventional film-forming device needed all of the steps of: cleaning the parts accumulated with dust, loading the parts accumulated with dust into the film-forming chamber, evacuating the film-forming chamber, initializing the vapor deposition sources, heating the vapor deposition sources, vapor depositing the materials on the substrate, replacing the substrates, and removing the parts accumulated with dust, as shown by the flowchart in Figure 10.

[0019] Therefore, an object of the invention is to provide a /4

film-forming device for an organic thin-film light-emitting diode that solves the problems of the film-forming devices of the prior art and facilitates the manufacture of an organic thin-film light-emitting diode with few defects at a high rate of operation.

[0020] [Means for Solving the Problems]

In order to solve the aforesaid problems, the present invention consists of the following aspects.

(1) A film-forming device for an organic thin-film light-emitting diode comprising an organic light-emitting layer which emits light by the recombination of electrons and positive holes; said film-forming device for an organic thin-film light-emitting diode characterized by comprising dust accumulating adhesion parts to be freely replaced, wherein parts, which are outside the element substrate inside a film-forming chamber, and are present in potions where an organic or inorganic material evaporated from its vapor deposition source is accumulated as dust, are mounted on the same support body.

[0021] (2) The film-forming device for an organic thin-film light-emitting diode of (1) above is a film-forming device in which a film-forming chamber is equipped, via a vacuum valve, with a load cell chamber to which a vacuum pump is connected in order to enable replacement of dust accumulating on a set of parts while maintaining said film-forming chamber in a vacuum state.

[0022] 3) The film-forming device for an organic thin-film

light-emitting diode of (1) or (2) above is a film-forming device comprising a preheating chamber having a temperature regulating means for said vapor deposition source and a means for maintaining the vacuum state as a chamber for performing an initialization operation of the vapor deposition source used in the film formation of an organic or inorganic material, with the preheating chamber being spaced apart from the film-forming chamber.

[0023] (4) The film-forming device for an organic thin-film light-emitting diode of (3) above is the film-forming device of Claim 3 wherein said preheating chamber is connected to said film-forming chamber via a vacuum valve to enable transfer of the vapor deposition source between the preheating chamber and the film-forming chamber while the film-forming chamber is maintained in the vacuum state.

[0024] (5) The film-forming device for an organic thin-film light-emitting diode of (4) above is a film-forming device comprising a plurality of the sets of parts accumulated with dust and the load lock chamber functioning as a preheating chamber.

[0025] (6) A film-forming device for an organic thin-film light-emitting diode comprising an organic light-emitting layer which emits light by the recombination of electrons and positive holes; said film-forming device for an organic thin-film light-emitting diode characterized by comprising a preheating chamber having a temperature regulating means for said vapor deposition source and a means for maintaining the vacuum state as a chamber for performing an

initialization operation of the vapor deposition source used in the film formation of an organic or inorganic material, with the preheating chamber being spaced apart from the film-forming chamber.

[0026] (7) The film-forming device for an organic thin-film light-emitting diode of (6) above, which is a film-forming device wherein said preheating chamber is connected to said film-forming chamber via a vacuum valve to enable transfer of the vapor deposition source between the preheating chamber and the film-forming chamber while the film-forming chamber is maintained in the vacuum state.

[0027] [Embodiments of the Invention]

The present invention will now be described specifically on the basis of the drawings. Moreover, each of the preferred embodiments of the present invention shown below is an example of a film-forming device for forming one organic layer or one inorganic layer, and a case is formed wherein cleaning of the parts accumulated with dust is performed after one light-emitting diode.

[0028] Figure 2 shows a preferred embodiment of the film-forming device of the present invention for forming one organic layer and one inorganic layer. The set of parts 13 accumulated with dust in Figure 2, which are parts present in portions where the organic or inorganic materials evaporated from their vapor deposition sources accumulated as dust, are integrally held by the same support. Vapor deposition source 8, a crucible 16, heating source 17, sensor 15, shutters 12, a mask, a shielding plate, and the like are cited as such parts. This

set of parts 13 accumulated with dust has a structure whereby it can be removed from a film-forming chamber 10 via a valve 11.

[0029] In such a structure, a plurality of the sets of parts 13 accumulated with dust are prepared, and while a prescribed vapor deposited thin film is being formed on an element substrate 9 in the film-forming chamber 10, when a separate set of parts 13′ accumulated with dust is cleaned, the next vapor deposition source 8′ is mounted, the next vapor deposited thin film is laminated, the vacuum valve 11 is opened, the set of parts 13 is removed and merely replaced with the set of parts 13′, and the film formation can be commenced. That is, as compared to a conventional case in which only the vapor deposition source 8 is replaced, the cleaning time for the set of parts 13′, in short, the number of cleaning steps for the parts accumulated with dust in the flowchart in Figure 10 can be mitigated, and the rate of operation of the film-forming device can be increased a corresponding amount.

[0030] Figure 3 shows a preferred embodiment in which a function for replacing the parts accumulated with dust while keeping the film-forming chamber in a vacuum state. The structure of this device is one in which a load cell chamber 19 was connected to the device with the structure shown in Figure 2 by way of the vacuum valve 11. This load cell chamber 19 is a chamber used for replacing the set of parts 13 accumulated with dust while keeping the film-forming chamber 10 of the film-forming device in a vacuum state; it has a structure in

which it is connected to a vacuum pump 18, and the set of parts 13 accumulated with dust can be mounted.

[0031] In such a structure, a plurality of the set of parts 13 accumulated with dust are provided, and while forming a prescribed vapor deposited thin film on the element substrate 9 in the film-forming chamber 10, a separate set of parts 13′ with dust mounted with the next vapor deposition source 8′ is cleaned, then installed in the load cell chamber 19, and this load cell chamber 19 is drawn into a vacuum by the vacuum pump 18 after closing a vacuum valve 11′, whereby the vacuum valve 11 is opened when the next vapor deposited thin film is laminated, the set of parts 13 is removed and merely replaced with the set of parts 13′, and film formation can be commenced. That is, as compared to a conventional case in which just a vapor deposition source 8 is replaced with using the load cell chamber 19, the cleaning time for the set of parts 13′ and the vacuum drawing time for the film-forming chamber 10, in short, the cleaning step for the parts accumulated with dust and the vacuum drawing step for the film-forming chamber in Figure 10 can be mitigated, while the rate of operation of the film-forming device can be increased a corresponding amount.

[0032] Figure 4 shows a preferred embodiment of a film-forming device provided with a preheating chamber 20 for performing an initialization operation of the vapor deposition source 8 used in the /5 film formation with the organic and inorganic materials. This

preheating chamber 20 has a source-temperature regulating function and a vacuum state maintaining function for the vapor deposition source 8, and is provided with the vapor deposition source 8′, sensor 15, a crucible 16′, the heating source 17, a vacuum pump 18′, etc. “Temperature regulating function” herein includes a heating or cooling function which is a function by the heating source 17 or the like to heat the vapor deposition sources in the preheating chamber 20. In addition, “vacuum state-maintaining function” is a function obtained by connecting the preheating chamber 20 to the vacuum pump 18′. In the illustrated example, the preheating chamber 20 has a structure in which it is spaced apart from the film-forming chamber 10 of the film-forming device.

[0033] In such a structure, while forming a prescribed vapor deposited thin film on the element substrate 9 in the film-forming chamber 10, the next vapor deposition source 8′ is loaded in the preheating chamber 20, the vacuum valve 11′ is closed, a vacuum is drawn with the vacuum pump 18′, initialization of the vapor deposition source 8′ is performed, the vacuum valve 11′ is subsequently opened, the vapor deposition source 8′ removed, whereby, when the next vapor deposited thin film is to be laminated, the valve 11 is opened, and the vapor deposition source 8 is removed from inside the shielding plate 22 and merely replaced with the vapor deposition source 8′, and the next film formation is commenced. That is, as compared to a conventional case in which just a vapor

deposition source 8 is replaced without using the preheating chamber 20, the initializing time of the vapor deposition source 8′, in short the step of initializing the vapor deposition source in Figure 10 can be mitigated, while the rate of operation of the film-forming device can be increased a corresponding amount.

[0034] In the preferred embodiment of the film-forming device provided with the preheating chamber 20 shown in Figure 4 above, in order to impart the film-forming device with the function for transferring the vapor deposition source 8 to the film formation chamber 10 from the preheating chamber 20 while keeping the film formation chamber 10 in a vacuum state, or from the film formation chamber 10 to the preheating chamber 20, the preheating chamber 20 in Figure 4 should be connected to the film formation chamber 10 via the vacuum valve 11. If this film-forming device is used, as compared to a conventional case in which the vapor deposition source 8 is merely replaced without using the preheating chamber 20, the step of initializing the vapor deposition source and the step of drawing the film-forming chamber into a vacuum in Figure 10 can be omitted, while the rate of operation of the film-forming device can be increased a corresponding amount.

[0035] Furthermore, when a film-forming device imparted with the temperature-regulating function for the vapor deposition source 8, which is a function of the preheating chamber 20 shown in Figure 4, is used in the load cell chamber 19 shown in Figure 3, as compared to

a conventional case in which a vapor deposition source 8 is merely replaced without using the load cell chamber 19 or preheating chamber 20, the step of initializing the vapor deposition source and the step of drawing the film-forming chamber into a vacuum in Figure 10 can be mitigated, while the rate of operation of the film-forming device can be increased a corresponding amount.

[0036] Figure 5 shows a preferred embodiment of the film-forming device provided with a function for loading a plurality of sets of parts 13 and 13b accumulated with dust in the film-forming chamber. A load lock and preheating chamber 21 provided with both the function of the aforesaid load lock chamber and the aforesaid preheating chamber is the chamber connected to the film-forming chamber 10 via the vacuum valve 11. This load lock and preheating chamber 21 has a structure that facilitates initialization of the vapor deposition source 8 therein. That is, it has a structure in which the heating source 17 can function for heating the vapor deposition source 8 if the set of parts 13 accumulated with dust is mounted on this load lock and preheating chamber 21. The "structure in which the heating source 17 can function for heating the vapor deposition sources 8" is such a structure that wiring, piping, and the like for supplying power to the heating source 17 can be completed along with mounting of the set of parts 13 accumulated with dust. On the other hand, the aforementioned load cell chamber 19 in Figure 3 has a structure in which the vapor deposition source 8 cannot be initialized in this

load cell chamber 19. That is, even if the set of parts 13 accumulated with dust is mounted in the load cell chamber 19, the heating source 17 for heating the vapor deposition source 8 does not function. The film-forming chamber 10 herein has a structure in which it is provided with a space and function for simultaneously loading the two set of parts 13 and 13b accumulated with dust.

[0037] In such a structure, a plurality of the set of parts 13 accumulated with dust are provided, and while forming the prescribed vapor deposition thin film on the element substrate 9 in the film-forming chamber 10, a set of parts 13b′ accumulated with dust mounted with a vapor deposition source 8b′ is subjected to a vacuum drawing in the load lock and preheating chamber 21, and the vapor deposition source 8b′ is initialized, the vacuum valve 11 is subsequently opened, the set of parts 13b accumulated with dust is loaded in the film-forming chamber 10, and further, the element substrate 9′ is loaded, whereby the next film formation is commenced immediately when the next vapor deposited thin film is laminated. That is, as compared to a conventional case in which the vapor deposition source 8 is merely replaced without using the load lock and preheating chamber, the cleaning time for the set of parts 13 accumulated with dust, the vacuum drawing time for the film-forming chamber 10, the initializing time for the vapor deposition source 8, the time for loading the element substrate 9 and the time for loading and removing the set of parts 13 accumulated with dust into/from the film-forming chamber 10,

in short, all the steps except the step of heating the vapor deposition source in Figure 10 and the step of vapor depositing the materials on the substrate can be mitigated, while the rate of operation of the film-forming device can be significantly increased a corresponding amount.

[0038] In addition, the set of parts 13b accumulated with dust in Figure 5 is provided with a function for backing up the set of parts 13 accumulated with dust. In short, when use of the vapor deposition source 8 becomes impossible because the organic and inorganic materials are used up and so forth, the vapor deposition sources used in the vapor deposition are switched from the vapor deposition source 8 to vapor deposition source 8b, whereby film formation is resumed immediately merely by heating the vapor deposition source 8b. That is, as compared to a conventional case in which the film-forming chamber in which the plurality of set of parts 13 accumulated with dust can be loaded and the load lock and preheating chamber are not used, when use of the vapor deposition source 8 becomes impossible, it is not necessary to resume all the steps except the step of heating the vapor deposition sources and the step of vapor depositing the materials on the substrate in Figure 5, while the rate of operation of the film-forming device can be increased a corresponding amount.

[0039] The film-forming device of the present invention is a film-forming device having the three forms, such as the batch-type,

the single-wafer-type, and the transfer-type, shown in Figures 7 to 9 and it can be respectively applied to a film-forming chamber with the shielding plate involving the respective vapor deposition sources 8a, 8b and 8c, mask, shutter, sensor, element substrate, etc.

[0040] [Practical Examples]

A case in which an N-number of organic or inorganic layers are formed is cited as an example. In this case, the rates of operation /6 of the film-forming device in the conventional examples and practical examples of the present invention are shown next.

(Conventional Example)

As shown in the flowchart in Figure 10, one batch of steps for the film-forming device is composed of the steps of: cleaning the set of parts accumulated with dust; drawing a vacuum in the film-forming chamber; initializing the vapor deposition sources; heating the vapor deposition sources; vapor depositing the materials on the substrate, replacing the substrate, and removing the set of parts accumulated with dust. The time required at each step was approximated as follows, respectively.

[0041] 1) Cleaning time for set of parts accumulated with dust: Although this was approximated for a 15-minute cleaning method, it was approximated as a time required for cleaning powdery dust by wiping or ultrasonically, using an organic solvent.

2) Time to load set of parts accumulated with dust in film-forming chamber (=time to remove set of parts accumulated with dust):

5 minutes

3) Time for vacuum drawing film-forming chamber: 60 minutes

This was approximated as the time needed to draw a vacuum to a pressure of about 10^{-6} Torr or less.

4) Time to initialize vapor deposition sources: 5 minutes

This time includes the initialization operation except the degassing operation of the vapor deposition source.

5) Time to heat vapor deposition sources: 5 minutes

6) Time to vapor deposit material on substrate: 5 minutes

This was approximated by vapor depositing a thin film to a thickness of 900Å at a vapor deposition rate of 3 Å/s.

7) Time to replace substrate: 1 minute

In addition, cleaning is performed on the set of parts accumulated with dust after forming M-number of N-number of layers of elements.

[0042] Therefore, the total time of one batch of steps is the total time {90+(10N+1)M} ion minutes of aforesaid 1 to 7 when N-number of organic or inorganic layers are formed by the film-forming device, with the time for operating the film-forming device corresponding to the vapor deposition time for the materials on the substrate {5NM} minutes. Therefore, the rate of operation of the film-forming device is expressed by: $\{5NM/\{90+(10N+1)M\}\times 100\%$. When $N=M=1$, the rate of operation of the film-forming device is 5%.

[0043] <Practical Example>

When the N-number of organic or inorganic layers are formed by a single-wafer-type film-forming device, a case in which the set of parts accumulated with dust are cleaned after the M-number of elements having N-number of layers are formed is cited as an example. A flowchart of the formation of N-number layers of a thin-film are formed when the type of film-forming device shown in Figure 10 is used is as shown in Figure 6. In short, as compared to the flowchart in Figure 10, while performing the steps of heating the vapor deposition sources and vapor depositing the material on the element substrate, both the steps until the set of parts contaminated with dust after use were removed from the film-forming chamber to the air and the steps until the contaminated set of parts accumulated with dust, which was already removed into the air, are loaded in the film-forming chamber after cleaning them can be conducted. Based on this flowchart, the rate of operation of the film-forming device is found according to the following expression:

(vapor deposition time of materials on substrate)/(vapor deposition sources heating time+vapor deposition time of materials on substrate)+ time to replaced substrate after forming N-number of layers of film) = $\{5NM/(10N+1)M\}\times 100\% = \{5N/(10N+1)\}\times 100\%$, and is about 50%. As compared to the 5% rate in the aforesaid conventional example, the rate of operation is improved about 10-fold.

[0044] [Advantages of the Invention]

As described above, in the film-forming device of the present

invention, an organic thin-film light-emitting diode with few defects can be manufactured at a high rate of operation.

[Brief Description of the Drawings]

[Figure 1] A cross section showing an example of a typical element structure of an organic thin-film light-emitting diode. [Translator's note: incomplete sentence] …a flowchart showing an example of one batch of steps for a film-forming device when … is not applied.

[Figure 2] A cross section showing a preferred embodiment of the film-forming device of the plastic optical element.

[Figure 3] A cross section showing another preferred embodiment of the film-forming device of the present invention.

[Figure 4] A cross section showing yet another preferred embodiment of the film-forming device of the present invention.

[Figure 5] A cross section showing still another preferred embodiment of the film-forming device of the present invention.

[Figure 6] A flowchart showing one example of one batch of steps for the film-forming device of the present invention.

[Figure 7] A cross section showing an example of of a conventional batch-type film-forming device.

[Figure 8] A cross section showing an example of a conventional single-wafer-type film-forming device.

[Figure 9] A cross section showing an example of a conventional

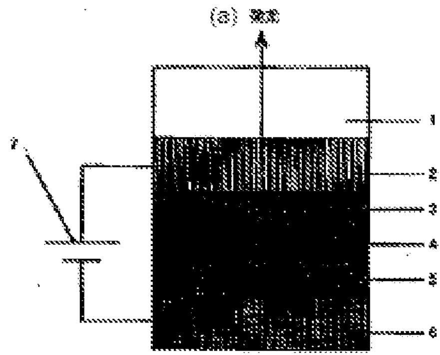
transfer-type film-forming device.

[Figure 10] A flowchart showing an example of one batch of steps for a conventional film-forming device.

[Explanation of the Reference Numerals]

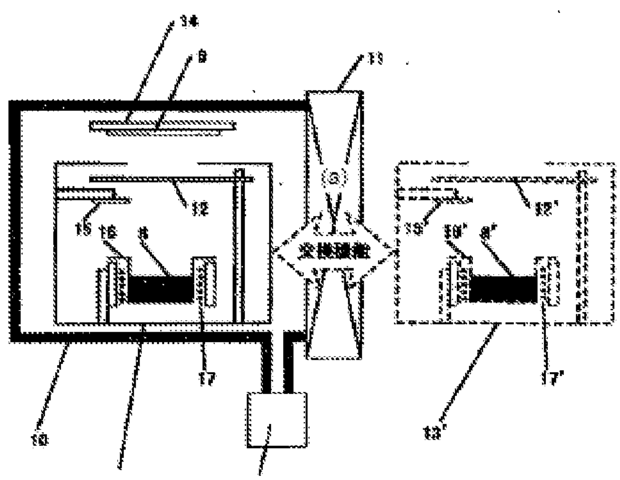
1: insulating light-transmitting substrate;
2: light-transmitting anode; 3: positive hole-injected layer;
4: light-emitting layer; 5: electron-injected layer;
6: cathode; 7: direct current power for driving;
8: vapor deposition source (8a: vapor deposition source A;
8b: vapor deposition source B; 8c: vapor deposition source C);
9: element substrate; 10: film-forming chamber (10a: film-forming chamber A; 10b: film-forming chamber B; 10c: film-forming chamber C);
11: vacuum valve; 12: shutter; 13: set of parts accumulated with dust; 14: substrate holder; 15: sensor; 16: crucible;
17: heating source; 18: vacuum pump; 19: load cell chamber;
20: preheating chamber; 21; load lock and preheating chamber;
22: shielding plate /7

[Figure 1]



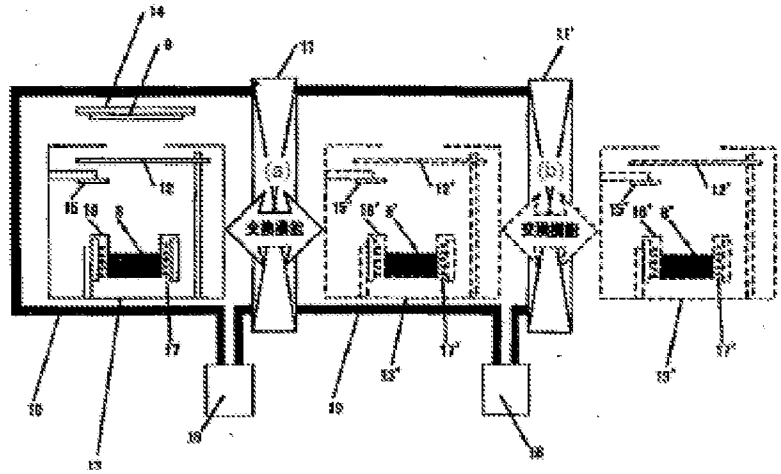
Key: (a) luminescence

[Figure 2]



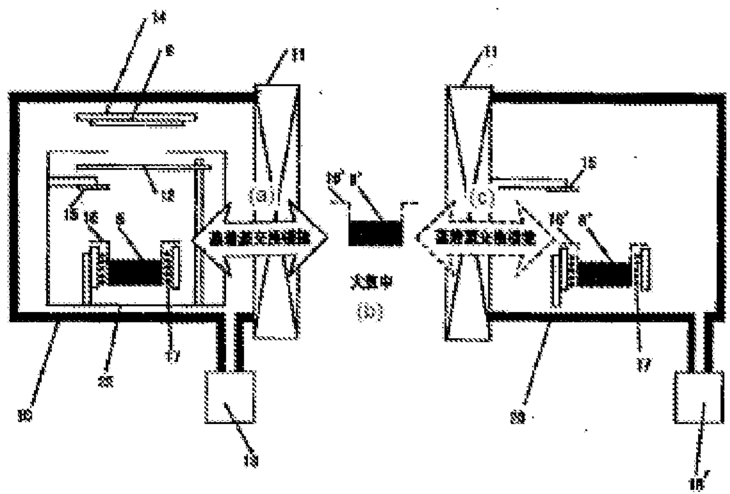
Key: (a) replacement function

[Figure 3]



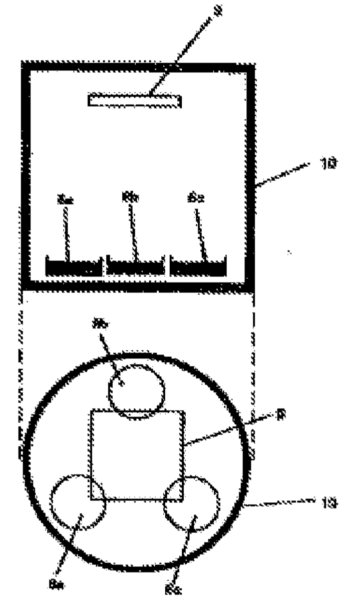
Key: (a) replacement function; (b) replacement function

[Figure 4] /8

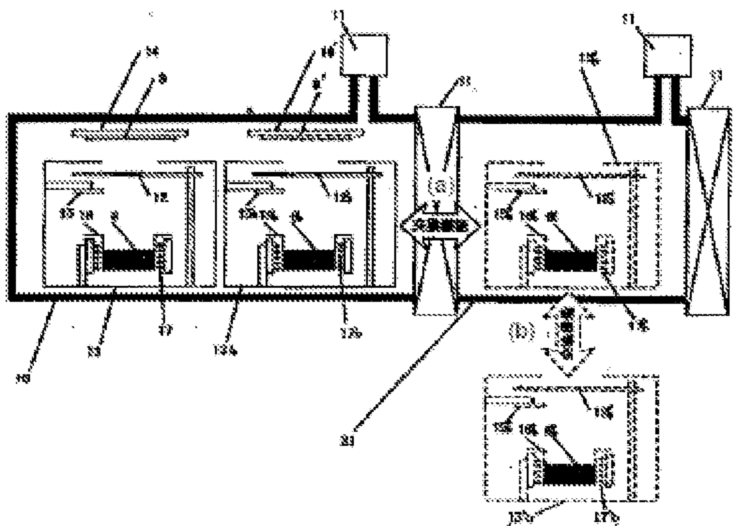


Key: (a) vapor deposition source replacement function; (b) in air; (c) vapor deposition source replacement function

[Figure 8]

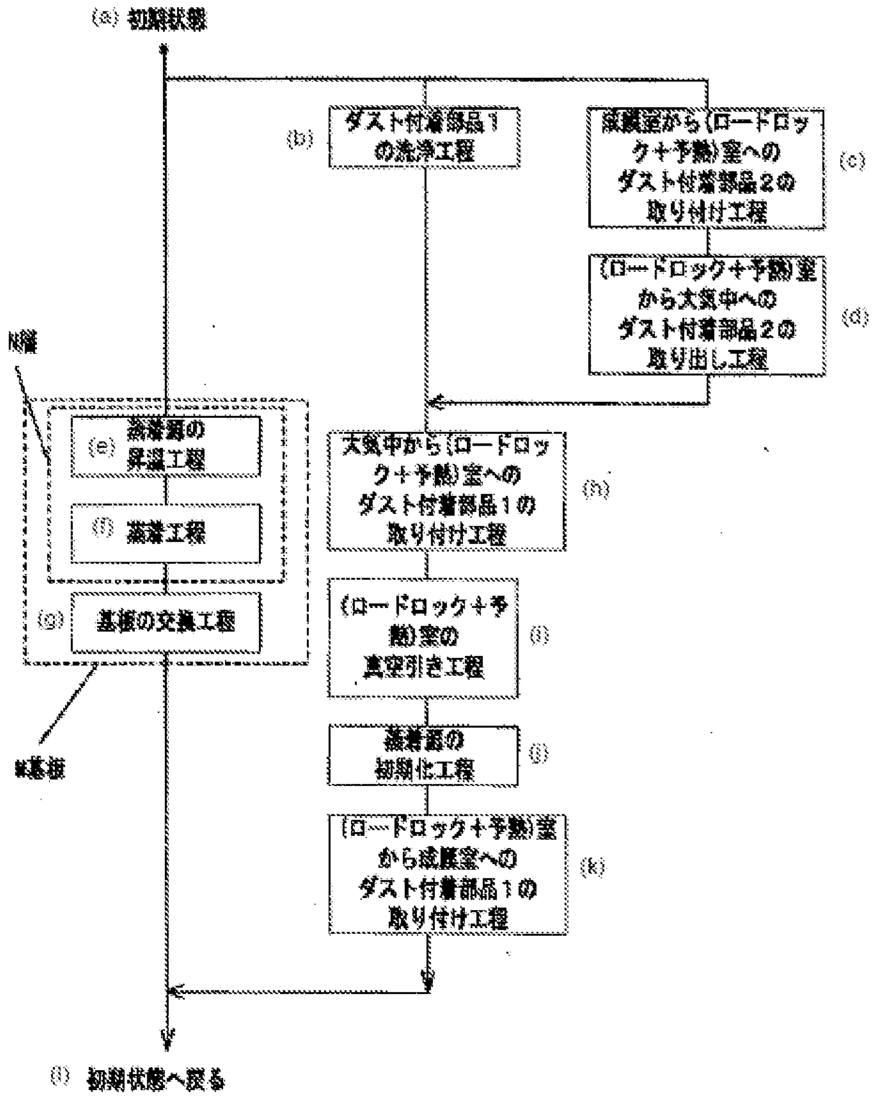


[Figure 5]



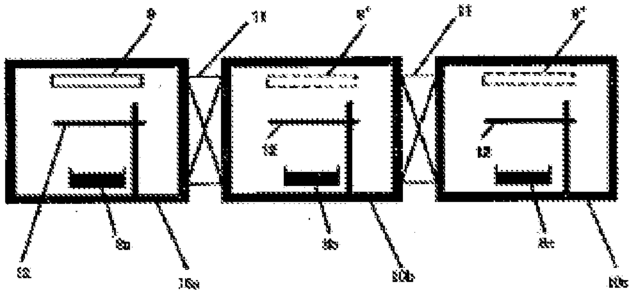
Key: (a) replacement function; (b) [illegible]

[Figure 6]

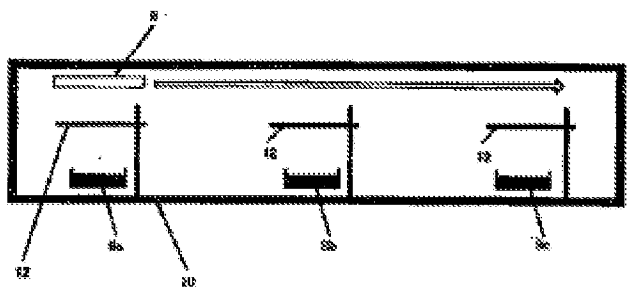


Key: (a) initial state; (b) Step of cleaning parts 1 accumulated with dust; (c) Step of loading parts 2 accumulated with dust into load lock and preheating chamber from film-forming chamber; (d) Step of removing parts 2 accumulated with dust into air from load lock and preheating chamber; (N) N-number of layers; (e) Step of heating vapor deposition sources; (f) vapor deposition step; (g) Step of replacing substrate; (M) M-number of substrates; (h) Step of loading parts 1 with dust accumulated into load lock and preheating chamber from air; (i) Step of drawing vacuum in load lock and preheating chamber; (j) Step of initializing vapor deposition sources; (k) Step of loading parts 1 accumulated with dust into film-forming chambers from load lock and preheating chamber; (l) return to initial state

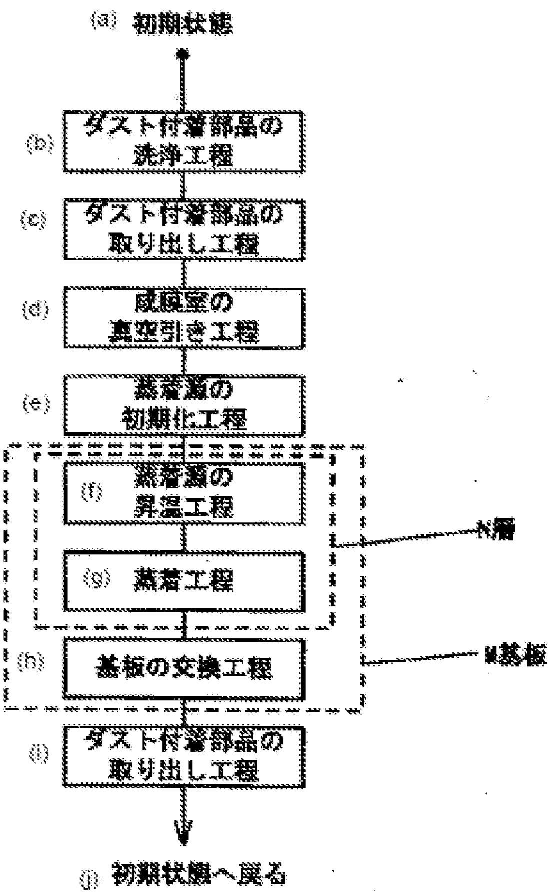
[Figure 7]



[Figure 9]



[Figure 10]



Key: (a) initial state; (b) Step of cleaning parts accumulated with dust; (c) Step of removing parts accumulated with dust; (d) Step of drawing vacuum in film-forming chamber; (e) Step of initializing vapor deposition sources; (f) Step of heating vapor deposition sources; (g) Step of vapor deposition; (h) Step of replacing substrate; (i) Step of removing parts accumulated with dust; (N) N-number of layer; (M) M-number of substrates; (j) return to initial state